

# A cross-sectional study of dental caries, intake of confectionery and foods rich in starch and sugars, and salivary counts of *Streptococcus mutans* in children in Spain<sup>1-3</sup>

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**ABSTRACT** In this cross-sectional study of 236 schoolchildren living in Manresa, Spain, we evaluated the association between prevalence of dental caries and frequency of consumption of various food groups, including sweetened baked goods and similar foods (rich in starch and sugars) and confectionery (rich in sugars but not starch), using a food-frequency questionnaire. Because *Streptococcus mutans* is associated with the cariogenicity of carbohydrates, we also evaluated the modification of these associations by salivary counts of this microorganism. Odds ratios (ORs) were used to measure the association between caries and tertiles of consumption. Sex, age, use of fluorides, tooth-brushing frequency, frequency of dental visits, socioeconomic status, and intake of other potentially cariogenic food groups were considered as potential confounders. We did not find a significant association between any of the food groups evaluated and caries prevalence. Failure to detect an association could have been due to the low prevalence of caries in our population (decayed, missing, or filled permanent teeth = 1.3 at age 10.6 y) or to underestimation of the association due to diet misclassification. In this population, the association between consumption of sweetened baked goods and caries appeared to be modified by the numbers of *S. mutans* [OR = 6.1 (95% CI: 1.6, 23.0) for low compared with high intake in children with moderate-to-high *S. mutans* counts and OR = 0.3 (95% CI: 0.1, 1.6) for low compared with high intake in children with low *S. mutans* counts]. These results suggest that a high intake of sweetened baked goods may be a determinant of caries prevalence in children with moderate-to-high salivary counts of *S. mutans*. *Am J Clin Nutr* 1997;66:1257-63.

**KEY WORDS** Caries, diet, carbohydrates, *Streptococcus mutans*, children, epidemiology, Spain, confectionery, sweetened baked goods

## INTRODUCTION

Dental caries is one of the most prevalent diseases in children worldwide. Although the prevalence of caries in developed countries is declining (1, 2), mainly because of the widespread use of fluorides, there still remains a subgroup of susceptible children at high risk of caries (3). Dental caries is a chronic-infectious process with a multifactorial etiology: dietary factors, oral microorganisms able to produce acids from sugars, and host susceptibility have to coexist for caries to

initiate and develop (4). Although sucrose is a well-established cause of caries (1, 2, 4, 5), epidemiologic studies conducted in developed countries after the implementation of preventive measures seem to indicate that the relative importance of sucrose in the development of caries has decreased in these countries (1, 4, 6-8). Many of these studies have led to contradictory results that could be partially explained by the fact that only a few studies (9-17) considered the effect of other factors involved in the complex relation between diet and caries, such as age, sex, socioeconomic status, use of fluorides, dental hygiene, or counts of oral microorganisms. Moreover, most studies classified foods into two groups according to the presence or absence of a minimum percentage of sucrose (10-20%), without taking into account the type of foods in which the sugars are present (10, 12-15, 17, 18). The few studies that evaluated the effects of specific foods have been based on crude statistical analyses (2, 19, 20), although there are some exceptions (9, 16, 21, 22).

Several experimental investigations have tried to establish the role of saccharides in dental caries by taking into consideration the effects of the industrial transformation rather than just focusing on the classic dichotomy between simple and complex carbohydrates. Manufacturing processes make saccharides more susceptible to the acid attack of oral bacteria (6, 23-25). Hence, it was suggested recently that some highly processed flavored snack foods containing hydrolyzed starch as the major carbohydrate could be at least as cariogenic as foods containing sugars but not starch (26-28). In addition, several reports indicate that the cariogenicity of starchy foods could be

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increased by the presence of relatively low quantities of sugar, suggesting that there is no simple relation between absolute food sucrose content and caries (24, 26, 29–33). This experimental body of evidence has not yet been specifically addressed in observational human epidemiologic studies. Starchy snack foods—including sweet and salted or flavored highly processed products—have a wide range of sugar-starch ratios and they are being consumed increasingly in industrialized countries, especially by children (34). The dental implications of this new pattern of consumption need to be investigated in human studies, and their effects should be distinguished from those of sugary foods without starch (confectionery).

In this study we evaluated the association between caries prevalence and intake of confectionery, which contains mainly sugars, and sweetened baked goods, which contain a mixture of starch and sugars. Because the presence of plaque microorganisms such as *Streptococcus mutans* is associated with the cariogenicity of carbohydrates (4, 35–37), we also evaluated the modification of the association between dietary intake and caries by salivary counts of this microorganism.

## SUBJECTS AND METHODS

### Study population

The present study was performed in 6–15-y-old schoolchildren living in Manresa in 1992. Manresa is a town of 66 000 inhabitants located in Catalonia, Spain, with a low fluoride concentration ( $< 0.3$  ppm) in drinking water supplies. The participants were selected by using a two-stage cluster random sampling, with schools in Manresa as the primary sampling unit, and all children from first (6–7 y old), sixth (11–12 y old), and eighth (13–15 y old) primary school grades as the secondary sampling unit. We randomly selected 10 schools with  $\approx 25$  children per grade. Of the 250 girls and boys who were invited to participate, 11 children from the first grade were excluded because their parents did not agree to their participation. Of the 239 schoolchildren who completed a 40-item food-frequency questionnaire (FFQ), three (12-, 13-, and 14-y old) were not included in the study because they did not complete the questionnaire properly. Thus, the analysis was based on 236 subjects (114 girls and 122 boys) with a mean ( $\pm$  SD) age of  $10.6 \pm 3.0$  y.

### Dietary assessment

The 40-item FFQ completed by the study subjects was a modified version of an open-ended, self-administered FFQ developed to assess the intake of caries-related foods in children (38). The items included the foods most frequently consumed by Spanish children containing sugars (mono- and disaccharides), sugar substitutes, or a mixture of starch and sugars. The questionnaire was completed during school hours with the aid of a nutritionist and with the additional collaboration of the children's parents. Participants were asked to indicate the average daily, weekly, or monthly frequency with which they consumed each food item over the previous year. Foods were categorized into nine groups based on carbohydrate content as well as on their physical characteristics: 1) confectionery items, which have a high sugar content and high adhesivity (toffees, sugared candies, sugared chewing gums, and chocolate without bread); 2) sweetened baked goods and other

foods with a mixture of non-raw starch and sugars with a wide range of starch-sugar ratios (bakery products, cakes, pastry, cookies, biscuits, doughnuts, bread with chocolate, sliced bread, and breakfast cereals); 3) honey and jam; 4) artificial sweeteners, sugarless candies, sugarless chewing gums, and sugar-free soft drinks; 5) milk and dairy products with sugars; 6) milk and dairy products without sugars; 7) liquid foods with saccharose, fructose, or both (soft drinks and fruit juices); 8) solid fruit (bananas, grapes, and apples); and 9) processed foods containing partially hydrolyzed starch without added sugars (potato chips and salted snacks). For each food item, subjects specified whether it was consumed at regular meal-times, between meals, or both. Sugar added to foods by children was not included in the food groups because the assessment of its consumption frequency had weak internal validity. The FFQ also included questions related to sugar and sugar substitute consumption, type of water drunk, number of regular mealtimes, and time of the day when these meals were consumed.

### Covariate assessment

From the questionnaires, information was also collected on children's ages, tooth-brushing habits, fluoride toothpaste use, fluoride mouth-rinsing habit, intake of fluoride supplements, and number of dental visits during the previous year. Children were categorized into three socioeconomic groups according to the school they attended: 39% were classified in the high group, 51% in the middle group, and 10% in the low group.

### Caries assessment

The dental examination was performed in the classrooms the same day of the diet assessment by a dentist whose caries diagnoses were compared with those of an expert (intraexaminer kappa statistic = 0.84), according to World Health Organization criteria (39). Dental caries was diagnosed by tactile examination under good natural daylight conditions by using a plain mouth mirror and a sharp probe. The instruments were disinfected by chemical procedures during the day and sterilized by heat at the end of each day. Enamel cavitation lesions on smooth surfaces, pit or fissure lesions where the probe was caught, dentinal caries, and deep caries of dentine with probable pulpal lesion were diagnosed as dental decay. Initial caries (caries spots) were not recorded and no radiographs were taken. From this information, the total number of decayed, missing, or filled permanent teeth (DMFT index) was calculated.

### Laboratory analyses

Samples from paraffin wax-stimulated saliva were collected from all schoolchildren by the same dentist who recorded caries status when he performed the examinations. A semi-quantitative test (Dentocult SM-Strip; Orion Diagnostica, Espoo, Finland) was used for the assessment of *S. mutans* salivary count (40). One milliliter saliva, collected by scraping a loop over the dorsum of the tongue, was transferred to a transport medium and brought to the laboratory according to the Beighton method (41). The samples were cultured on mitis-salivarius-saccharose-agar culture for 48 h. The *S. mutans* count was recorded as the number of colony-forming units per liter (CFU/L) saliva. Children were categorized into four

groups according to *S. mutans* numbers:  $< 1 \times 10^6$  CFU/L,  $1 \times 10^6$  to  $< 10^7$  CFU/L,  $1 \times 10^7$  to  $< 1 \times 10^8$  CFU/L, and  $\geq 1 \times 10^8$  CFU/L.

### Statistical analyses

Odds ratios (ORs) were used as the measure of association between diet and caries. The outcome was defined as a dichotomous variable according to the DMFT index. A DMFT index of 3, corresponding to the top 20% of the population, was used as the cutoff point. Thus, cases were defined as children with  $\geq 3$  caries and controls as children with  $< 3$  caries. All consumption frequencies were transformed into servings per week and food group intakes were categorized in tertiles of consumption. The following potential confounders were considered: sex, age, high-fluoride water intake (regular compared with irregular or no consumption), fluoride supplement consumption (regular compared with irregular or no consumption during the previous year), fluoride mouth rinsing with 2% NaF solution in a school-based preventive program ( $\geq 2$  y compared with  $< 2$  y), tooth-brushing frequency (one or more times per day compared with less than once a day), frequency of dental visits (one or more times compared with no visits during the previous year), socioeconomic status (three categories), and consumption of the food groups of no direct interest in this study (tertiles). The adjusted ORs for caries across tertiles of consumption were calculated by using logistic-regression models. Consumption tertiles were introduced as dummy variables, taking the lower tertile as the reference group. In the final models we tested for monotonic trend by assigning each participant the median value for the category and modeling this variable as continuous.

To examine whether the association between food consumption and caries risk was modified by *S. mutans* numbers (ie, presence of a multiplicative interaction between food consumption and *S. mutans* count), the authors estimated adjusted ORs and 95% CIs separately for subjects with *S. mutans* salivary counts  $< 1 \times 10^7$  CFU/L and for those with *S. mutans* salivary counts  $\geq 1 \times 10^7$  CFU/L. A level of significance of 0.05 for two-tailed tests was chosen. The STATA 3.1 statistical package (Statistics and Data Analysis, Stata Corporation, College Station, TX) was used for the analyses.

### RESULTS

The mean ( $\pm$  SD) DMFT index in the 236 schoolchildren studied was  $1.3 \pm 2.2$  and the mean age of the children was  $10.6 \pm 3.0$  y. The percentage of children free of caries in permanent teeth was 60.2% and the proportion of children who had a DMFT score  $\geq 3$  was 19.9%.

Most children reported four to five regular meals per day: 92.9% of children had breakfast, 44.5% a midmorning snack, 97.1% lunch, 85.7% a midafternoon snack, and 98.7% had dinner. The food groups that were consumed mostly at non-regular hours were confectionery (94.1%), salted snacks (68.4%), and sweet beverages (59.3%), whereas the food groups consumed mostly at regular mealtimes were dairy with sucrose (77.4%), dairy without sucrose (72.2%), honey and jam (67.7%), fruit (62.7%), and sweetened baked goods and similar foods (56.4%). Ninety-two percent of the children reported adding sucrose to one or more foods, especially to dairy prod-

ucts (51.9%) and fruit juices (24.8%), whereas only 3.4% consumed artificial sweeteners. The mean and median consumption values of the nine food groups considered are shown in Table 1.

Related to the use of fluorides, 88.8% of the children reported using fluoride-containing toothpaste and 71.4% mouth rinsing with fluoride solutions at least twice a month, whereas only 7.1% of the children reported consuming fluoride supplements. Sixty-four percent of the children had visited a dentist at least once during the previous year.

The distribution of selected variables across tertiles of intake of foods rich in starch and sugars is shown in Table 2. The intake of confectionery, the proportion of boys, and the percentage of children with salivary counts of *S. mutans*  $\geq 1 \times 10^7$  CFU/L was greater with greater food consumption.

As compared with children in the lowest tertile of intake of confectionery, children in the second and third tertile groups had an age-adjusted OR for caries of 1.3 (95% CI: 0.5, 3.5) and 1.8 (95% CI: 0.7, 4.2), respectively (test for trend:  $\chi^2_{1df} = 1.7$ ,  $P = 0.2$ ) (Table 3). After further adjustment for sex, salivary counts of *S. mutans*, and consumption of sweetened baked goods, the OR for caries was 1.3 (95% CI: 0.5, 3.5) for the second tertile group and 1.4 (95% CI: 0.5, 3.7) for the third tertile group, with the first tertile group of consumption as the reference (test for trend:  $\chi^2_{1df} = 0.3$ ,  $P = 0.6$ ) (Table 3).

As compared with children in the lowest tertile group of intake of sweetened baked goods and similar foods, children in the second and third tertile groups had an age-adjusted OR for caries of 2.5 (95% CI: 1.0, 6.4) and 1.9 (95% CI: 0.8, 4.4), respectively (test for trend:  $\chi^2_{1df} = 1.2$ ,  $P = 0.3$ ) (Table 3). After further adjustment for sex, salivary counts of *S. mutans*, and consumption of confectionery, the OR for caries was 2.1 (95% CI: 0.8, 5.9) for the second tertile group and 1.9 (95% CI: 0.7, 5.0) for the third tertile group, with the first tertile group of consumption as the reference (test for trend:  $\chi^2_{1df} = 1.0$ ,  $P = 0.3$ ) (Table 3).

**TABLE 1**  
Frequency of consumption of nine food groups by 236 participants<sup>1</sup>

Food group	Frequency of consumption
	servings/wk
Confectionery <sup>2</sup>	10.5 $\pm$ 15.1 (5.3)
Sweetened baked goods and others <sup>3</sup>	17.6 $\pm$ 14.9 (13.7)
Honey and jam <sup>4</sup>	1.4 $\pm$ 3.1 (0.0)
Artificial sweeteners and artificially sweetened foods <sup>5</sup>	4.4 $\pm$ 6.7 (2.3)
Milk and dairy products with sugars	8.5 $\pm$ 7.3 (7.0)
Milk and dairy products without sugars	10.4 $\pm$ 11.4 (7.0)
Beverages with sugars <sup>6</sup>	9.0 $\pm$ 10.7 (7.0)
Fruit <sup>7</sup>	9.3 $\pm$ 9.6 (7.0)
Salted snacks	2.6 $\pm$ 4.2 (1.2)

<sup>1</sup>  $\bar{x} \pm$  SD; median in parentheses.

<sup>2</sup> Toffees, sugared candies, sugared chewing gums, and chocolate without bread.

<sup>3</sup> Bakery products, cakes, pastries, cookies, biscuits, doughnuts, breads with chocolate, sliced breads, and breakfast cereals.

<sup>4</sup> Honey and jam.

<sup>5</sup> Sugarless candies, sugarless chewing gums, and sugar-free soft drinks.

<sup>6</sup> Soft drinks and fruit juices.

<sup>7</sup> Bananas, grapes, and apples.

TABLE 2

Age-standardized distribution of selected variables by intake of sweetened baked goods and similar foods in 236 schoolchildren

Variable	Tertile of intake of sweetened baked goods and similar foods <sup>1</sup>		
	Low (0.0–8.8 servings/wk)	Moderate (8.9–17.8 servings/wk)	High (17.9–64.4 servings/wk)
Confectionery <sup>2</sup>	3.1	5.8	10.5
Median age (y)	10.8	9.6	11.6
Males (%)	45.3	47.8	55.9
Rinsing with fluoride (%) <sup>3</sup>	38.2	35.5	41.9
Brushing of teeth (%) <sup>4</sup>	79.7	86.8	69.7
<i>Streptococcus mutans</i> (%) <sup>5</sup>	40.4	43.1	44.4
Median DMFT index <sup>6</sup>	0.7	1.0	0.7
DMFT3 index (%) <sup>7</sup>	15.4	24.1	21.7

<sup>1</sup> Bakery products, cakes, pastries, cookies, biscuits, doughnuts, breads with chocolate, sliced breads, and breakfast cereals.

<sup>2</sup> Toffees, sugared candies, sugared chewing gums, and chocolate without bread.

<sup>3</sup> Children with  $\geq 2$  y reported rinsing with fluoride.

<sup>4</sup> Children reporting brushing their teeth at least once a day.

<sup>5</sup> Children with salivary counts  $\geq 1 \times 10^7$  CFU/L of *S. mutans*.

<sup>6</sup> DMFT, number of decayed, missing, and filled permanent teeth.

<sup>7</sup> Children with a DMFT index  $\geq 3$ .

After consumption of the other food groups was included, fluoride supplement consumption, fluoride mouth rinsing, tooth-brushing frequency, frequency of dental visits, and socioeconomic status in a multivariate-logistic-regression model, the estimated ORs and 95% CIs for confectionery and sweetened baked goods were practically unchanged. Because none of these potential confounders contributed significantly to the model, they were excluded from the final model presented in Table 3.

The presence of oral microorganisms that are able to produce organic acids from the metabolism of fermentable dietary carbohydrates—mainly *S. mutans* and *Lactobacillus acidophilus*—is a necessary condition for the initiation and development of dental caries. Because *S. mutans* is the most relevant cariogenic bacteria in children, we assessed whether the association between caries prevalence and intake frequency of confectionery and foods rich in starch and sugars was modified by the salivary count of *S. mutans*. The modification of these associations by *S. mutans* was investigated through a stratified analysis for children with salivary counts  $< 1 \times 10^7$  CFU/L and for those with  $\geq 1 \times 10^7$  CFU/L. Results are presented in Table 4. Of the children with low *S. mutans* counts, greater intake of sweetened baked goods and similar foods was not associated with a greater prevalence of caries (Table 4). However, of children with moderate-to-high counts of *S. mutans*, those with medium and high intakes had a prevalence of caries about three- and sixfold, respectively, higher than children with low intakes (Table 4) [likelihood ratio test (LRT) for multiplicative interaction:  $\chi^2_{2df} = 10.3$ ,  $P = 0.006$ ]. When we considered  $1 \times 10^8$  CFU/L as the cutoff point, results were in the same direction but the precision of the estimates decreased because of the small number of cases with high counts of *S. mutans* [OR = 0.7 (95% CI: 0.2, 2.7) for high compared with low intake of sweetened baked goods and  $< 1 \times 10^8$  CFU *S. mutans*/L, and OR = 19.0 (95% CI: 1.4, 254.7) for high

TABLE 3

Odds ratios (ORs) and 95% CIs for the association between caries and intake of sweetened baked goods and similar foods among 236 schoolchildren<sup>1</sup>

Variables	OR	95% CI
Age-adjusted intake of sweetened baked goods and similar foods		
Low (0–8.8 servings/wk)	1.0	—
Moderate (8.9–17.8 servings/wk)	2.5	(1.0, 6.4)
High (17.9–64.4 servings/wk)	1.9	(0.8, 4.4)
P for trend	0.3	
Multivariate logistic regression of intake of sweetened baked goods and similar foods <sup>2</sup>		
Low (0–8.8 servings/wk)	1.0	—
Moderate (8.9–17.8 servings/wk)	2.1	(0.8, 5.9)
High (17.9–64.4 servings/wk)	1.9	(0.7, 5.0)
P for trend	0.3	

<sup>1</sup> Intakes of bakery products, cakes, pastries, cookies, biscuits, doughnuts, breads with chocolate, sliced breads, and breakfast cereals were based on the tertile distribution among the control group.

<sup>2</sup> Controlled for age, sex, *Streptococcus mutans* count  $< 1 \times 10^7$  or  $\geq 1 \times 10^7$  CFU/L, and frequency of confectionery intake (toffees, sugared candies, sugared chewing gums, and chocolate without bread).

compared with low intake of sweetened baked goods and  $\geq 1 \times 10^8$  CFU *S. mutans*/L; LRT for multiplicative interaction:  $\chi^2_{2df} = 11.4$ ,  $P = 0.003$ ].

Finally, when we assessed the interaction between confectionery intake and concentrations of *S. mutans* with adjustment for intake of foods rich in starch and sugars, there was a suggestion of an increased risk of caries prevalence associated with confectionery intake among children with moderate-to-high counts of *S. mutans* [OR = 2.8 (95% CI: 0.7, 11.6) for the second tertile group and OR = 2.5 (95% CI: 0.7, 9.0) for the third tertile group, with the first tertile group as the reference], but not among children with low counts of *S. mutans* [OR = 0.5 (95% CI: 0.1, 2.3) for the second tertile group and OR = 0.6 (95% CI: 0.1, 2.7) for the third tertile group, with the first tertile group as the reference]. However, our data did not provide enough evidence to reject the null hypothesis of homogeneity (LRT for multiplicative interaction:  $\chi^2_{2df} = 3.2$ ,  $P = 0.2$ ).

## DISCUSSION

In this observational study, high intake of foods rich in sugars but not starch (confectionery) was not significantly associated with an increased prevalence of dental caries. On the other hand, high intake of foods containing a mixture of starch and sugars (sweetened baked goods and others) was associated with an increased prevalence of dental caries in children with moderate-to-high salivary counts of *S. mutans* (OR = 6.1; 95% CI: 1.6, 23.0) but not in children with low counts of *S. mutans* (OR = 0.3; 95% CI: 0.1, 1.6).

The association between intake of sucrose and dental caries has been well established in numerous studies conducted mainly in northern and western European countries and in North America (2). The evidence comes from clinical trials (42), prospective cohort studies (9, 22, 43), ecologic studies (44), and studies in special populations (45), as well as from animal experiments (46). The unexpected lack of association

TABLE 4

Odds ratios (ORs) and 95% CIs for the association between dental caries and intake of sweetened baked goods and similar foods stratified by salivary counts of *Streptococcus mutans*<sup>1</sup>

<i>S. mutans</i> count	Tertile of intake of sweetened baked goods and similar foods <sup>2</sup>					
	Low		Middle		High	
	OR <sup>3</sup>	95% CI	OR <sup>3</sup>	95% CI	OR <sup>3</sup>	95% CI
< 1 × 10 <sup>7</sup> CFU/L	1.0 (6/41) <sup>4</sup>	—	2.0 (6/44)	0.5, 8.4	0.3 (3/39)	0.1, 1.6
≥ 1 × 10 <sup>7</sup> CFU/L	1.0 (6/26)	—	2.6 (9/20)	0.7, 10.3	6.1 (17/19)	1.6, 23.0

<sup>1</sup> Significant modification of the association between intake of sweetened baked goods and similar foods and dental caries by *S. mutans* salivary counts,  $p = 0.006$  (test for multiplicative interaction: likelihood ratio test,  $\chi^2_{2df} = 10.3$ ).

<sup>2</sup> Intakes were based on the tertile distribution of the control group.

<sup>3</sup> Adjusted for age, sex, and frequency of confectionery intake (toffees, sugared candies, sugared chewing gums, and chocolate without bread).

<sup>4</sup> Cases/controls in parentheses; cases were children with an index of decayed, missing, or filled permanent teeth ≥ 3; controls were children with an index of decayed, missing, or filled permanent teeth < 3.

between confectionery intake and dental caries in our study could be explained by underreporting of confectionery intake by children with high caries rates. Another explanation for this lack of association is that children with more caries could have decreased their confectionery intake to control caries after receiving advice from their dentist. These types of biases could also have affected past retrospective studies that failed to detect an association between sucrose intake and caries (2). Moreover, the lack of association between confectionery intake and caries found in our study could also be due to the relatively low prevalence of caries in our population.

The observed association between intake of sweetened baked goods and caries is supported by various experimental studies that have shown that starch increases the cariogenic potential of sucrose and other sugars (24, 26, 29–33, 47–49). In an analysis of 22 foods consumed commonly in the United States, Mundorff et al (32) concluded that the cariogenic potential of foods containing hydrolyzed starch and sugars is stronger than would be expected by the absolute sucrose content of these foods. The mechanism by which starch added to sucrose increases the cariogenic potential of a food could be that the presence of starch increases the retention time of the food in the mouth (25, 50). Also, there are some indications that starch can increase the acid production from sucrose when both nutrients are present together (51).

Our data also suggest that the association between intake of sweetened baked goods and caries is modified by the salivary count of *S. mutans*. Specifically, this association seemed to be present in children with moderate-to-high salivary counts of *S. mutans* (≥ 1 × 10<sup>7</sup> CFU *S. mutans*/L) but not in children with lower counts (< 1 × 10<sup>7</sup> CFU/L). This finding suggests that there could be a threshold in the number of oral *S. mutans* colonies to allow fermentable carbohydrates to exert a harmful effect on the teeth. This is supported by experimental research, which indicates that both a cariogenic diet and a certain *S. mutans* count need to coexist for caries to develop (2, 4, 35–37). van Houte (37) suggested that there is a sequence of events from high carbohydrate intake to high numbers of *S. mutans* in dental plaque to increased caries activity. However, this seems to be an oversimplification of the complex relation between diet and caries. Some ecologic studies showed that this sequential relation does not always exist in human populations (52–55). In our data, we found that only 22% of children with a high frequency of sweetened baked goods

consumption had moderate-to-high salivary *S. mutans* counts and high caries prevalence, and that only 52% of children with a low frequency of sweetened baked goods consumption had low counts of *S. mutans* and low caries activity.

Misclassification of categorical variables could introduce over- or underestimation of associations (56, 57). To minimize misclassification, trained nutritionists completed the dietary questionnaires by personal interview with the children and with the aid of their parents. We also included items in the questionnaire to check for consistency of the answers and we checked by telephone contact the answers that seemed too extreme or not consistent. Misclassification of intake of sweetened baked goods is likely to be nondifferential with respect to caries prevalence because there is no reason to believe that children with higher rates of caries overreported their intake of sweetened baked goods. This type of misclassification could introduce heterogeneity of the stratum-specific ORs if misclassification of the amount of food depends on the concentration of *S. mutans*, which is highly unlikely.


As indicated earlier, it is possible that children with more caries have decreased their confectionery consumption to control caries on the advice of their dentist. However, these changes in dietary habits are unlikely to apply to foods with starch and sugars because these foods are usually not considered to be important in the prevention of caries.

To minimize confounding by the intake of other foods, we included all food groups studied in the multivariate analyses. After adjustment for confectionery, sweetened baked goods and other foods containing starch and sugars were still associated with caries, a result that supported an independent association of the latter food group with caries.

Insufficient interindividual variation in diet was unlikely to have explained the lack of association between diet and caries because the range of frequency of intake was wide: it varied from no to five times per day. Finally, another limitation of our study was that, because of the limited number of children included in the study, the CIs around our estimates were wide, especially when we assessed the effect modification by *S. mutans* counts.

In summary, this study suggests a positive association between frequency of intake of foods containing a mixture of starch and sugars and dental caries prevalence limited to children with moderate-to-high salivary counts of *S. mutans*. However, public health recommendations should await the results



of further epidemiologic studies to confirm the relative cariogenicity of these kinds of foods, including those with < 10% sugar. This study also highlights the importance of considering the effect of salivary numbers of microorganisms, which metabolize carbohydrates to acids, on the estimation of the cariogenicity of foods and on the identification of population groups at high risk of caries. 

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